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Extension

Cariboo Forest Region, BC

A New Instrument for Measuring Shade Provided by Overhead Vegetation

INTRODUCTION

A previous Extension Note (Teti, 1999) described the significance of summertime stream temperature to fish habitat and forest practices in the Horsefly River watershed and summarized the results of a literature review on this topic. One of the findings was that the major mechanism by which land use can change the temperatures of streams during the summer is by changing the amount of direct solar radiation falling on the water. Removing riparian vegetation which provides shade increases a stream's maximum daily temperature on clear summer days when temperatures tend to be highest and this can also increase the stream's mean daily temperature.

If we have a watershed in which summertime stream temperature is a serious issue, the literature indicates that the logical method for managing temperature is to manage riparian shade. A cautious approach might be to leave generous riparian reserves on all streams. However, a more quantitative approach would allow decisions to be made more rationally. This can be achieved by understanding how much stream shade there is in different parts of the watershed, how it changes in response to human activities, and how it affects temperature. This requires that shade be defined and that it be measurable. Fortunately, progress has been made on this as we found in the literature review.

Wooldridge and Stern (1979) and Beschta, et. al. (1987) recognized the importance of direct solar radiation to stream heating and suggested a measure of shade which they called "angular canopy density" (ACD). They defined this as the portion of the sky occupied by canopy along the sun's path between 1000 AM and 200 PM. They noted that shade is particularly important as a

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source of stream heating during this time period for a number of reasons. However, we were not able to find a suitable instrument for measuring ACD. A variety of instruments were considered including fisheye photography (followed by digital analysis of the images), the Solar Pathfinder, the shperical densiometer (Lemmon, 1956), and an angular canopy densiometer described by Belt, et. al. (1992). None of these met our requirements of low cost, convenience, speed, and accuracy so we developed a new instrument. This extension note describes it and reports on a test of its accuracy.

Our instrument was designed to measure angular canopy density defined by the above authors so we refer to it as an "angular canopy densiometer" and an "ACD meter".

INSTRUMENT DESCRIPTION

Our ACD meter consists of a hinged clamshell case containing a convex mirror, a bubble level, a magnetic compass, and a fixed eyesight. The version described here is constructed of varnished Baltic Birch plywood and is shown in Figure 1. Its dimensions are 30 x 11 x 3 centimetres and it weighs 380 grams. The principle of operation is similar to that of the Lemmon densiometer. The user makes an ocular estimate of canopy density in a view reflected in a convex mirror. However, there are important differences between our instrument and the Lemmon densiometer.

- The sun's path is delineated.
- It provides more accurate orientation relative to the celestial hemisphere.
- It provides a clearer image of the canopy.

We calibrate our instruments by drawing reference lines on the mirror corresponding with the portion of sky of interest. Our reference has been the sun paths from 1000 to 1400 hours local solar time between mid-July and mid-August at 52 degrees north latitude. We obtained coordinates for these sun positions from a U.S. government web site ("Ephemeris Generator" http://ssd.jpl.nasa.gov/cgi-bin/eph) and transferred them to the mirror. The mirror can be calibrated to show locations of the sun corresponding with any desired time of day, time of year, and observer latitude.

The left side of Figure 2 shows what the user sees in the mirror and the right side of the figure shows reference locations in the celestial hemisphere. The celestial hemisphere is an observer's imaginary unobstructed view of the sky and polar coordinates provide a reference using azimuth and angle above the horizon. It corresponds with a vertically oriented, 180 degree fisheye photograph.

Figure 2 shows that the portion of sky of interest for angular canopy density is relatively small. We divided this into four equal sections corresponding with one hour of sun travel because this makes ocular estimates of canopy density easier. We estimate canopy density in each of these sections and average them to get an ACD estimate for each ground location.

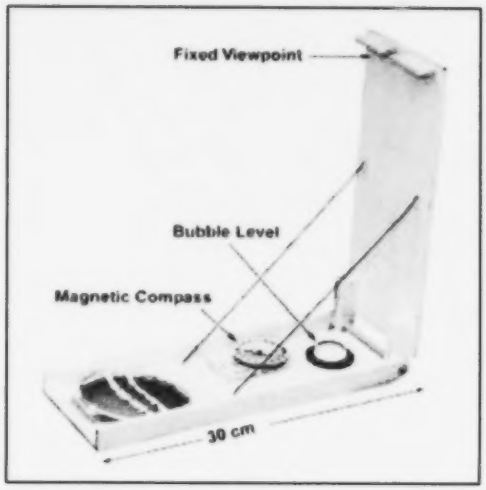

Figure 1. Angular Canopy Densiometer

Many foresters are familiar with the Lemmon densiometer because it has been available for years as a general canopy density measurement device. For comparison with our ACD meter, Figure 3 shows the location of grid lines on a sample Lemmon densiometer in polar coordinates when viewed as directed while facing south. The lines are irregular due to distortion in the mirror.

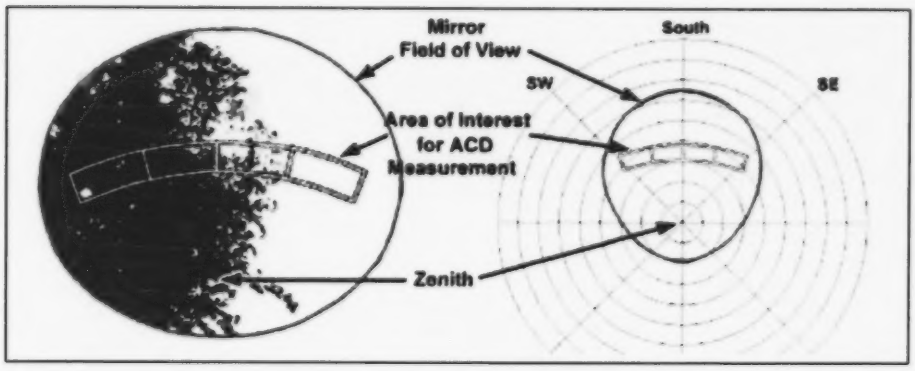

Figure 2. Sample view in our ACD meter (left)
and reference locations in polar coordinates (right).

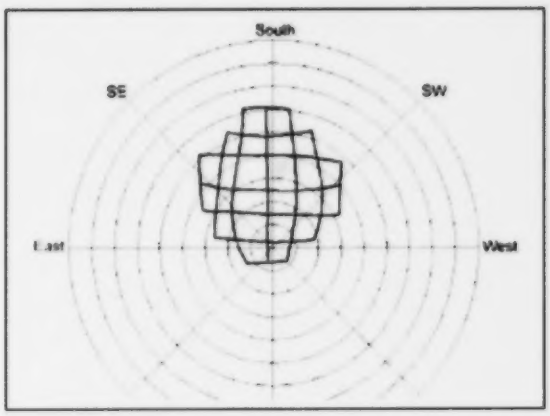

Figure 3. Location of Lemmon densiometer grid in polar coordinates when facing south as measured on a sample instrument.

INSTRUMENT EVALUATION

Our criteria for a convenient ACD meter are:

1. It should define a suitable area of interest relative to actual sun path.
2. It should be small and light.
3. It should allow a reading to be taken quickly.
4. It should have an acceptable accuracy.

The first two criteria were satisfied by the instrument design as described in the preceding section. It fits easily in the back of a field vest. The third criterion was found to be met during tests. The instrument can be easily oriented and read while being hand held. Positioning it, taking readings, and dictating them to a field assistant can be accomplished in about 15 seconds. One of the reasons this is important is that stream shade can vary in a complex way over the surface of a stream, thus requiring a number of readings to be made over the width and length of a stream reach if one wishes to obtain statistically useful data. An instrument which requires several minutes per reading or which is awkward to carry while wading a stream is not practical for this purpose.

The last criterion, accuracy, was tested by comparing ocular estimates of ACD made in the field with computer pixel counts of ACD from photographs using another instrument. This was a larger version of our ACD meter, having an 8 inch mirror instead of a 4 inch mirror, and a 35 mm camera mounted at the viewpoint. The increasing quality of canopy images between the Lemmon densiometer, our small ACD meter, and our 8 inch reference instrument is shown in Figure 4.

Coincidentally, we found that the top row of six squares in grid of the Lemmon densiometer we examined corresponded very closely with the area of interest for ACD estimates when it is pointed south (compare Figures 2 and 3). However, we found it to be poor for estimating the density of fragmented vegetation due to the quality of its mirror. Also, it is difficult to ensure a consistent orientation of the viewer's eye relative to the mirror. This limits the accuracy with which the

Lemmon densiometer's grid can be oriented with respect to the celestial hemisphere.

In our test, we assumed that photographs of canopy in the 8 inch reference instrument mirror (e.g. bottom of Figure 4) captured the "true" angular canopy density. However, we needed a way to objectively measure it from photographs under a variety of lighting conditions. To achieve this, we processed all digitized images at a later time using a consistent procedure in Adobe Photoshop which made use of colour information to classify sky pixels as sky and foliage pixels as foliage even when foliage appeared as bright green against a dark blue sky.

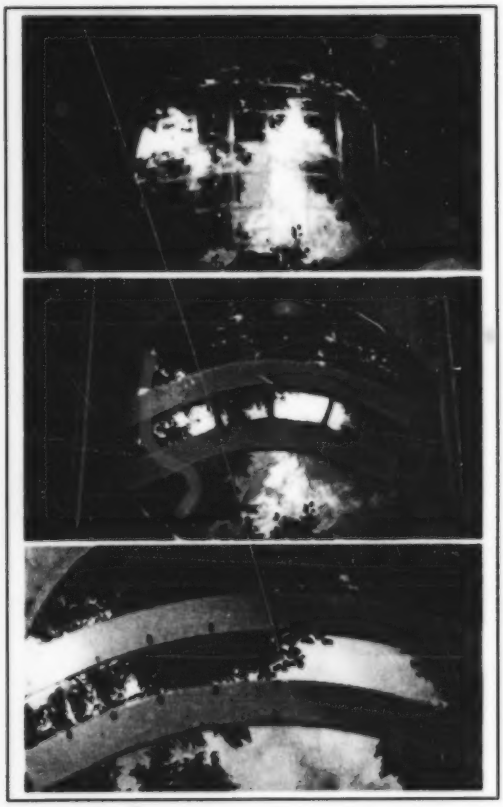

Figure 4. View of the same canopy in a Lemmon densiometer, our 4 inch ACD meter, and our 8 inch reference instrument.

In our test, we sampled only canopies with fragmented foliage such as that in Figure 4 rather than a representative range of canopies because the densities of very heavy canopies and very light canopies are easy to estimate while fragmented canopies are more difficult. Our sample did not include any zero canopy or 100 percent canopy because the error is virtually zero in those cases.

Our test procedure was as follows:

- Select a location with fragmented canopy.
- Make an ocular estimate of ACD in the field with our small ACD meter.
- Photograph the canopy in the 8 inch ACD meter.
- Repeat the above for a number of field sites.
- Digitize images, process them to distinguish canopy pixels from sky pixels, and calculate ACD from pixel counts using SigmaScan™ software.

RESULTS

The accuracy of our small ACD meter is illustrated by a scattergram of readings obtained from computer pixel counts versus ocular estimates made in the field with our instrument. This is shown in Figure 5, which also show the results of linear regression and 95 percent confidence limits on the regression line. The value of r^2 was 0.78.

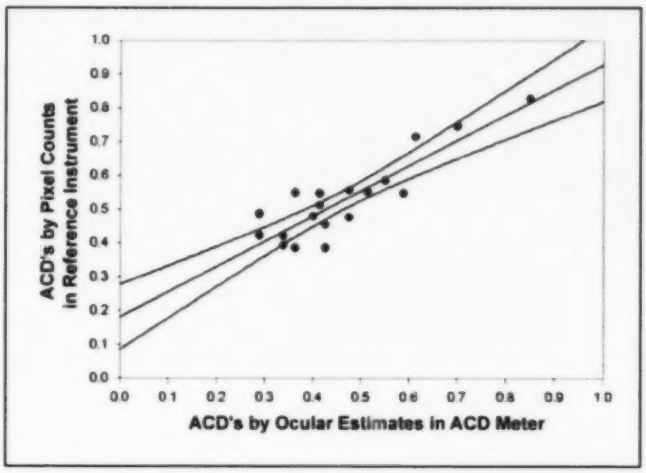

Figure 5. Comparison of our instrument with the reference method.

DISCUSSION

The best instrument for measuring shade depends on one's objectives. Our objective is to be able to accurately characterize shade as angular canopy density over the width and length of a stream reach. This requires an instrument which is small, light, provides results quickly, and is accurate under a wide variety of canopy conditions.

The closest existing method which we could find that was intended for this purpose was the angular canopy densiometer described by Belt, et. al. (1992). It is not a commercial product but is a general description of a device. It specifies a one foot square flat mirror which we judged to be inconvenient

and hazardous to the operator's eyes under sunny conditions. Another instrument that we considered was the "Solar Pathfinder" but it is designed to identify large obstructions to sunlight such as in passive solar energy applications, not for quickly estimating the density of vegetation along the sun's path. We considered it impractical for our purposes as well.

We found that using a Lemmon densiometer in a slightly modified way could provide the user with a good indication of the part of the canopy that is relevant for angular canopy density but that it does not provide a clear image of a fragmented canopy, thereby making canopy density estimates difficult. It is not our intent to criticize the Lemmon densiometer because it was not designed for this purpose. However, it has been used in recent years by some researchers to estimate stream shade, perhaps more because no other simple instrument was available than because it was appropriate.

Our test was designed to represent near worst-case conditions for estimating ACD in that we sampled only highly fragmented canopy. The accuracy of ocular estimates of canopy density would tend to be better under a full range of canopy conditions because the errors approach zero as canopy density approaches either zero or 100 percent. We expect that if our sample had included a full range of canopy conditions, our regression line would have been closer to y=x and that the correlation would have been higher. We plan to repeat this test to determine if this is true.

Our ACD meter was found to provide what we consider a good balance of compact size, speed, and accuracy when its purpose is to sample angular canopy density over the width and length of a stream reach. We will be using it to characterize stream shade as a function of surrogate variables such as stream width, seral stage, and biogeoclimatic zone and we hope to be able to develop a predictive relationship for angular canopy density. If successful, this will help make it possible to manage stream shade at the watershed scale, thereby improving our ability to manage stream temperature in the presence of land use which modifies riparian vegetation.

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